Dispersion Modelling at HSL

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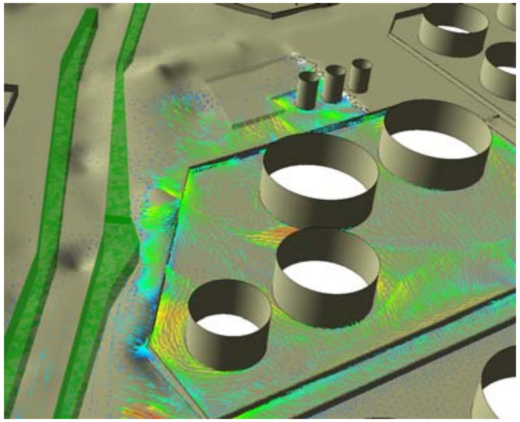
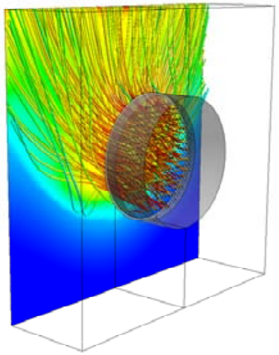
Health & Safety Laboratory

- Over 300 staff of which more than a third hold doctorates.
- Experience across all H&S sectors, including:
  - Fire and process safety
  - Computational modelling
  - Exposure control
  - Toxicology etc.
- 550 acre test site
- Tunnels / fire galleries
- Impact track
- Cat 3 microbiological lab



Dispersion Modelling

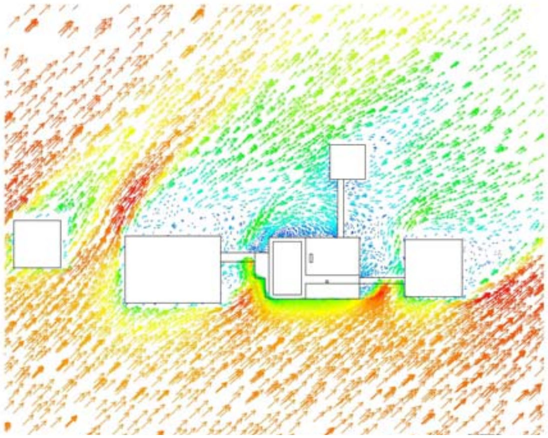
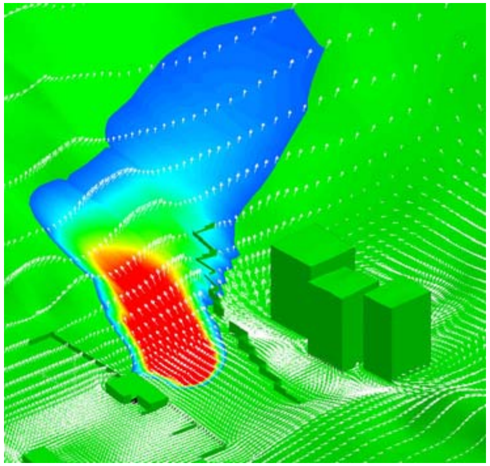
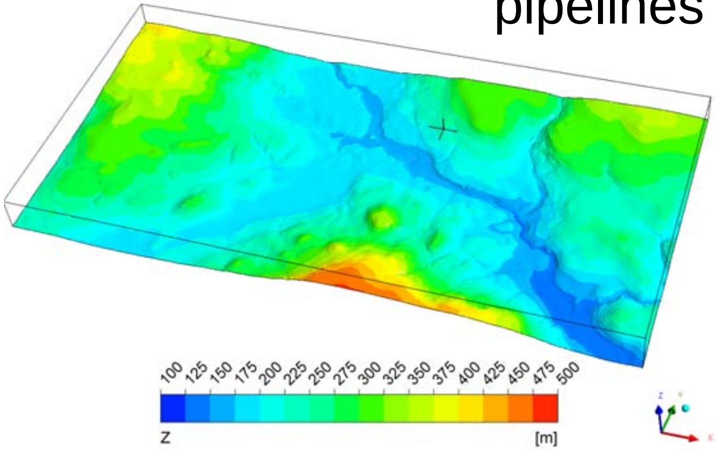
HEALTH & SAFETY LABORATORY

- Buncefield Incident investigation





- Gas releases from offshore platforms
- Chlorine dispersion
- CO_2 releases from pipelines

Smoke Infiltration into TRs

HEALTH & SAFETY LABORATORY

- Cullen Report into the Piper Alpha disaster: Temporary Refuge (TR) must be provided on all offshore installations
- TR performance standards: survivability when exposed to a Major Accident, including ingress of smoke, flammable and toxic gas

- Air tightness of TR measured using blower door tests
- Current guidance based on TR endurance time recommends 0.35 ACH

Offshore Information Sheet No. 1/2006 “Testing Regime for Offshore TR-HVAC Fire Dampers & TR Pressurisation Requirements http://www.hse.gov.uk/offshore/trhvac.pdf

HSL/MMI Project

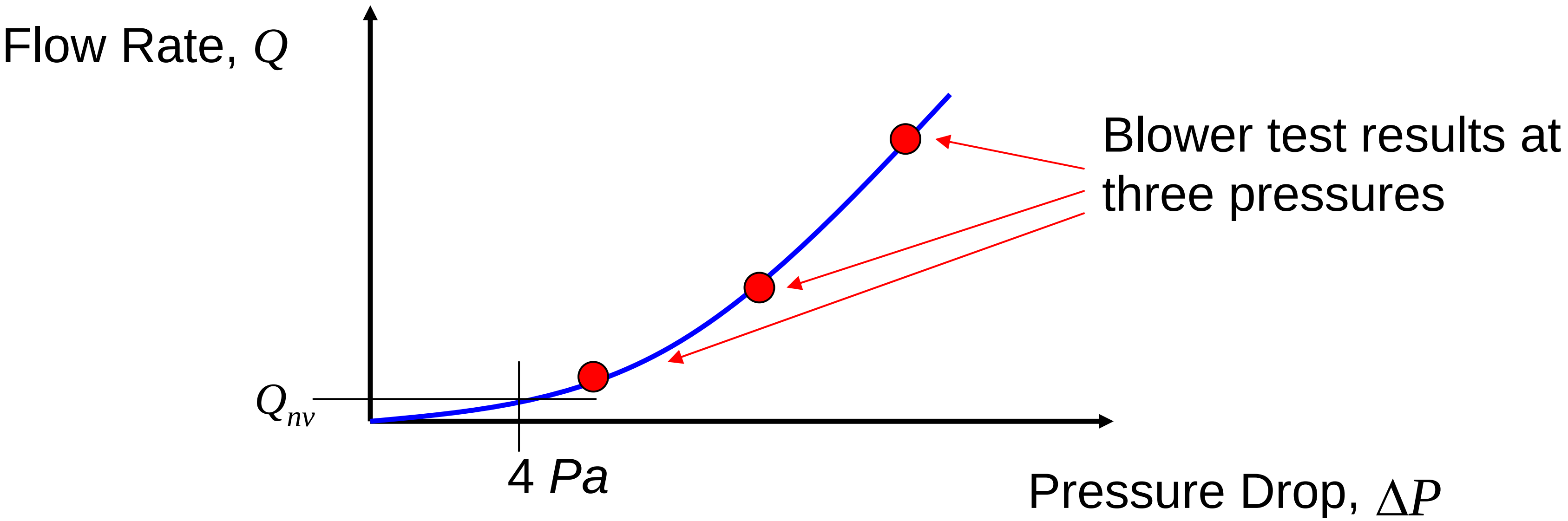
- Aims:
  - To develop a model to predict the time to impairment in the TR (infiltration, toxic effects)
  - To understand model sensitivities and identify important factors
  - To investigate scientific basis of 0.35 ACH
  - To work jointly with MMI who are developing EI standard for blower-door testing

- Budget: £40k (HSL), £20k (MMI)
- Timescales: Oct 2011 – Oct 2012

Model Development

- Determination of air change rate
- Infiltration modelling
- Effect of occupants
- Effect on occupants
- Implementation
- Sensitivity analysis

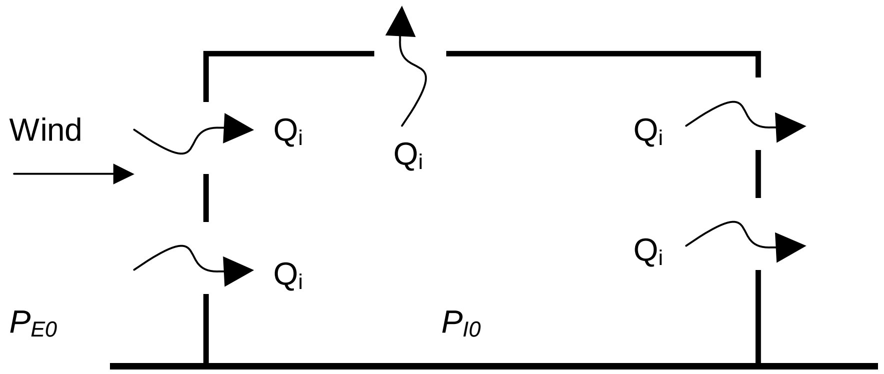
Air change rate calculation



- Fit data to curve: $Q = k\left(\Delta P\right)^n$
- Assume pressure drop across openings ⌘ 4 Pa in case of natural ventilation
- Find Q_{nv} from curve and velocity using Bernoulli
- Determine "Effective Leakage Area"

Air change rate calculation

- Distribute ELA as porosity on TR exposed sides
- Include other openings e.g stuck damper
- Wind and stack effects

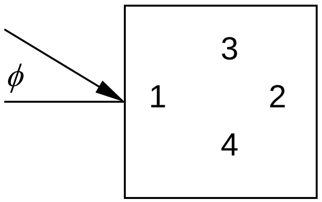


- For any opening:

$$\Delta P_i = P_{E0} - P_{I0} - g z_i (\rho_E - \rho_I) + 0.5\, C_p \rho_E U_W^2$$

Air change rate calculation

- Pressure coefficients as a function of wind angle (ASHRAE fundamentals F26.6)



$$C_p(\phi) = \frac{1}{2}\Big\{ \left[C_p(1) + C_p(2)\right]\left(\cos^2\phi\right)^{1/4} + \left[C_p(1) - C_p(2)\right]\left(\cos\phi\right)^{3/4} + \left[C_p(3) + C_p(4)\right]\left(\sin^2\phi\right)^2 + \left[C_p(3) - C_p(4)\right]\sin\phi \Big\}$$

$C_p(1)$ = with wind at 0°
$C_p(2)$ = with wind at 180°
$C_p(3)$ = with wind at 90°
$C_p(4)$ = with wind at 270°
ϕ = wind angle clockwise from normal to wall 1

- Calculate flow rate through each opening:

$$Q_i = Cd_i \ \mathrm{sgn}(\Delta P_i) A_i \sqrt{\frac{2|\Delta P_i|}{\rho}}$$

- Solve for the internal pressure *(P_{i0})* to satisfy continuity
- Calculate air change rate, Q/V

Infiltration modelling

- CSTR model:

$$V\frac{dC_i}{dt} = QC_i - QCe_i + Source_i$$

C_i = interior concentration of component i

Ce_i = exterior concentration of component i

i = CO, CO_2, N_2, O_2

- Sources (i.e. effect of occupants on concentrations)

$$SourceO_2 = -RMV \times RQ \times \%O_2$$

$$SourceCO_2 = RMV \times RQ \times \%O_2$$

$$RMV = \exp(0.2496 \times \%CO_2 + 1.9086)$$

RQ = Respiratory quotient (0.83)

RMV = Respiratory Mean Volume

Effect on occupants

- Fractional Effective Dose (or additive) model
- Used for CO, CO_2 and oxygen depletion

$$FED = \underbrace{\frac{TL}{SLOT}}_{CO_2} + \underbrace{\frac{\%COHb}{30}}_{CO} + \underbrace{\frac{Drop\ in\ SaO_2}{10}}_{O_2}$$

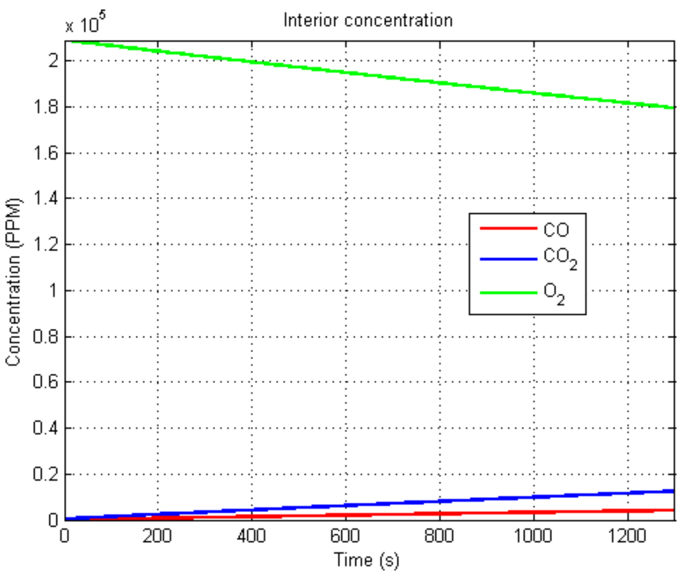
- Impairment at: FED ❍ 1

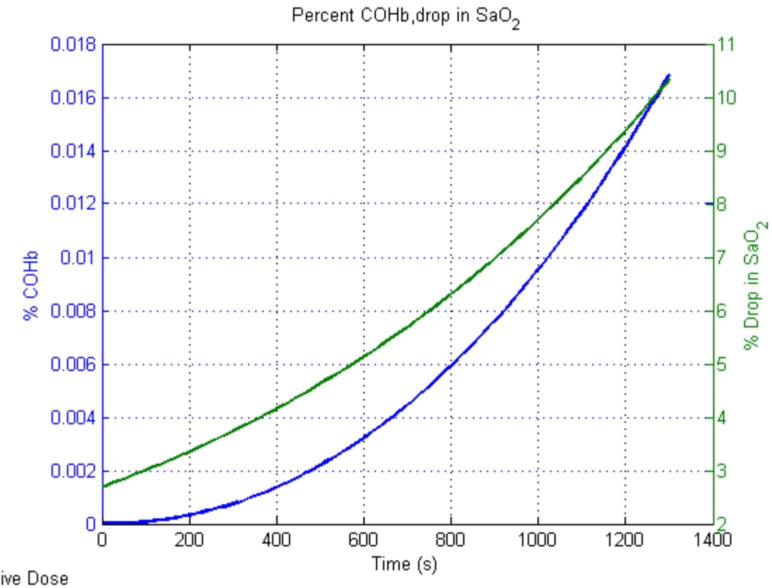
Sample results

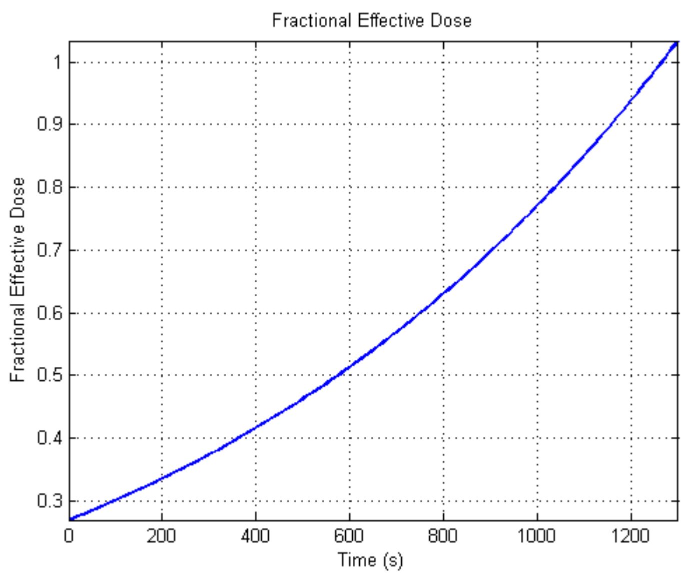
- 300 m^3 TR
- 10 occupants
- 5 m/s windspeed orthogonal to face 1
- Initial conditions (ppm):

Component	External	Internal
CO	30000	0
CO_2	82000	385
O_2	0	209000

Sample results





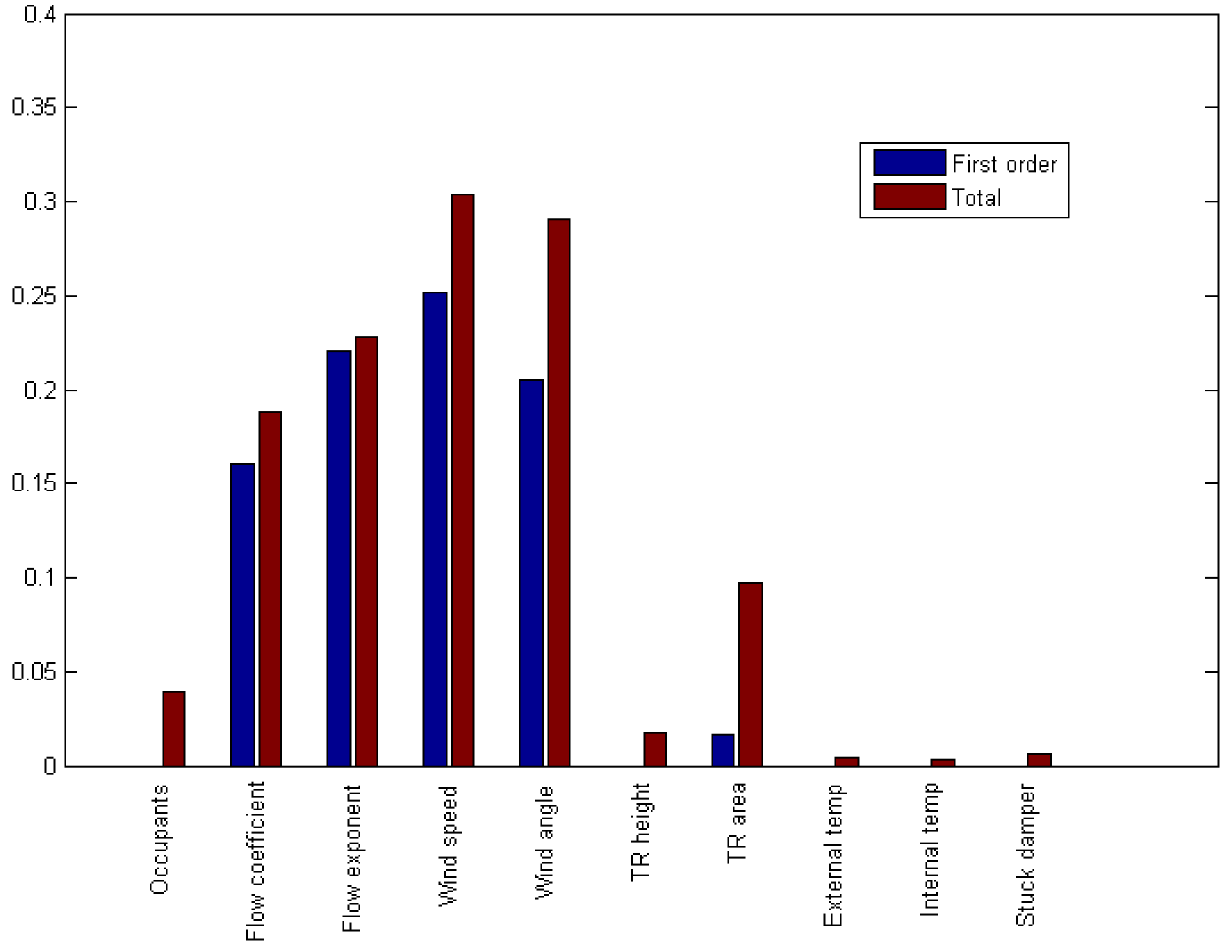


Sensitivity Analysis

- Sensitivity analysis using Winding Stairs method

First order sensitivity influence of each input

Total sensitivity: level of interaction of each input



Ongoing Work

- Model verification
- Further sensitivity analysis
- Testing with “realistic” scenarios

- Deliverable:
  - HSL Report
    - Describing model
    - Identifying important parameters
    - Appendix with worked examples

Other Ongoing Activities

HEALTH & SAFETY LABORATORY

- Sensitivity/uncertainty analysis: combining statistical techniques and phenomenological dispersion models
- Sensor networks: new experiments + modelling
- PhD/MSc project on QUIC validation for dense gas releases
  - Selection of validation test cases
  - Recommendation on universities (Surrey?)
  - Interested in collaborating?